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THE QUALITY OF WATER AT DIFFERENT POINTS ON A WATER SYSTEM[1]

By Sheppard T. Powell[2]

The quality of water at the point of purification is frequently quite different from the quality of the same water drawn by the consumer from the distribution main. The percentage of increase or decrease in the numbers of bacteria and the B. coli content of the water supply at these different points may be so slight as to excite but little comment either by the health authorities or by the men in charge of the operation of the system. A review of the operating results of thirty-two different municipal water plants showed that in 92 per cent of these systems there was an increase in the number of bacteria from the point of purification to the tap water samples. These increases ranged from about 2 per cent to 500 per cent. In the majority of the systems the increase was slight.

The reason for a change in the quality of the water cannot be accounted for readily in all instances. Local operating conditions and methods of treatment and distribution must be taken into consideration to determine definitely just why the results at different points on a system vary. In specific instances there are radical changes in operation that may result in wide fluctuations from year to year, or from season to season.

A condition of this kind has been noted in The Baltimore County Water and Electric Company's system supplied from the Avalon Filtration Plant. The depreciation in the quality of the water after passing through one of the distribution reservoirs of this Company's system, during the summer months of 1919 and 1920 has been so marked that it necessitated intensive study to definitely determine the causes responsible for the results obtained.

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[1] Presented at the Cleveland Convention, June 8, 1921. Discussion of this paper is requested and should be sent to the Editor.

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Before entering into a discussion of these results it is well to describe briefly the Company's water supply system with reference to the method of purification, the distribution system and the reservoir.

The Avalon Plant of this Company was installed about 1900. The method of purification at that time was slow sand filtration without sterilization.

The raw water supply is drawn from the Patapsco River and from Rockburn Branch. The former is subject to considerable pollution and often becomes excessively turbid. The latter is a small spring stream, comparatively clear, which receives little sewage contamination. After purification the water is pumped to Catonsville and other suburban[3] territory adjacent to Baltimore City. The water is pumped first to a 400,000 gallon standpipe which is operated in conjunction with a 4,000,000 gallon reservoir. When the standpipe is filled, the water is by-passed to this reservoir. From here the water is pumped to Mt. Washington, Towson, Lutherville and other towns supplied by the Company.

In 1908 it became necessary to increase the purification facilities and two mechanical filters, having a combined capacity of 1,000,000 gallons per 24 hours, were constructed. From 1908 to 1910 these filters were operated in conjunction with the slow sand plant and gave satisfactory results. In the latter year the water was treated with hypochlorite of lime prior to filtration. In 1916 three filter units were added, giving a total filter capacity from the mechanical filters of 2,500,000 gallons per day.

During the summer of 1919 it was noted that there was a marked increase of the number of B. coli and of the total bacterial count in the tap waters from one portion of the Company's distribution system.

Mr. Morse, Chief Engineer of the State Department of Health of Maryland, suggested that the chlorine dose be split, applying a portion of the chemical before filtration, with a secondary dose after the water had passed through the mechanical filters. This was done and at the same time a record was kept of the residual chlorine in the filtered water at the filtration plant. Although the dose of chlorine was steadily increased there was no improvement in the quality of the water drawn from the taps.

Careful study was then undertaken by the Engineering Force of the State Department of Health, the City Bacteriologist, the writer and Dr. Eaton, of the School of Hygiene of Johns Hopkins

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[3] A large portion of this territory has been annexed to Baltimore City.

University, who acted as referee becteriologist. The findings of this investigation showed that the poor quality of tap water was restricted almost entirely to the territory supplied with water from the distribution reservoir at Catonsville.

As shown in figure 1, the water delivered from the filtration plant, after filtration and chlorination, from 1915 to date, never exceeded a monthly average content of more than 10 bacteria per cubic centimeter, when grown on gelatine at 20°C. The water from the taps prior to passage through the Catonsville reservoir averaged in most instances less than 10 per cubic centimeter, but in 1920, during three months, this average was above 20 per cubic centimeter.

There has always been a slight increase in the bacterial count after the passage of water through the reservoir in question, but during 1919 and 1920 the numbers of bacteria in the reservoir water became very great. This condition was even more marked in the B. coli content of the water, as shown graphically in figure 2. These results have been set forth in comparison with the chlorine applied to the filtered water and the residual chlorine in the treated water at the Avalon Filtration Plant. From these records it is seen clearly that the B. coli content in the tap water was entirely independent of the dose of chlorine or the amount of residual chlorine in the treated water at the point of treatment.

The B. coli content of the tap water samples reached its peak during the summer months, falling off rapidly when cold weather set in. This condition was very marked in the reservoir water.

During the months of June and October, 1920, there was also an increase in the number of B. coli in the tap water, before passage through the reservoir. These two high points can be accounted for by the fact that in these months comparatively few samples were taken, so that a single positive sample in one-tenth of 1 cc. greatly increased the average for the month.

The condition to which we wish to draw attention is that prior to 1919 the B. coli content of the tap waters came well within the United States Treasury Department Standard, while in the summer of 1919 the coli content became excessive after passage through the reservoir, in spite of the fact that the chlorine applied was high. As soon as cold weather set in conditions again became normal. The quality of the water in the summer of 1920 became bad again, and continued so until cold weather appeared.

In attempting to arrive at some explanation for this condition many factors were taken into consideration.

It will be noted, as shown in figure 1, that there was no correlation between the quality of the untreated water and the results of the filtered and tap samples. Also, as shown in figure 3, no correlation could be drawn between the temperatures and the bacterial content of the tap waters, as it will be seen from this figure that the temperature curve is quite uniform from year to year.

The Catonsville reservoir is well protected against any possible chance of sewage contamination. The reservoir, which contains 4,000,000 gallons of water, is surrounded by a bank about 8 feet high and there is a 5-foot fence running around the entire property. During the entire day there is a man on duty at the pumping station and no one is permitted to enter the grounds. The water in the reservoir is several feet higher than the surrounding territory and there has always been leakage from this reservoir. The reservoir is situated in a suburban territory with dwellings 100 or 200 yards away but extreme care has always been exercised to prevent local contamination.

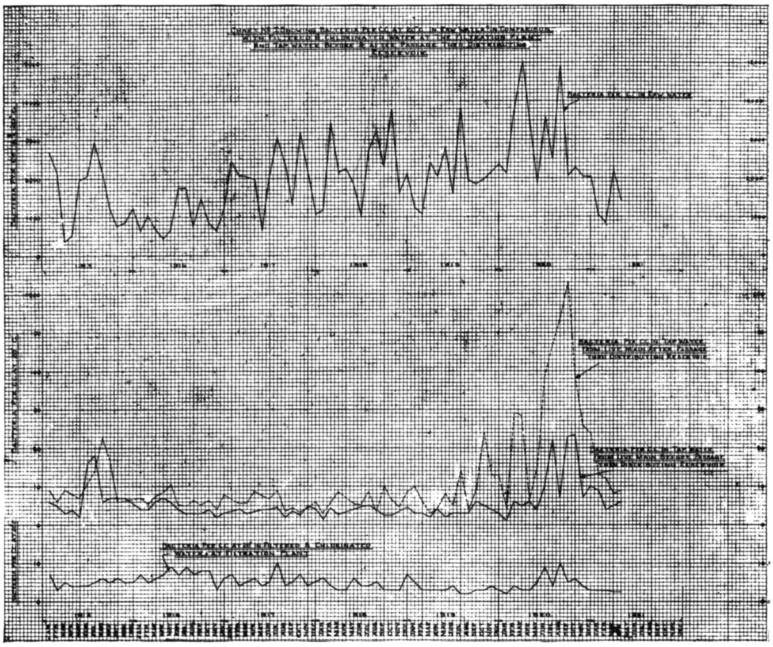

Fig. 1

As a result of the study that has been made to determine the cause of the unusual condition that has been noted in this investigation one fact stands out prominently.

Prior to 1919 tadpoles were present in small numbers in the reservoir water. Most of these tadpoles were of the common toad or leopard frog type. No great numbers of tadpoles or bullfrogs were ever noted in this reservoir. It might be well to point out at this time that the tadpoles propagating from the spawn of bullfrogs do not change into frogs in one season but may live in the water for one, two or three years before they reach a frog state. These tadpoles are very large, some of them measuring 6 to 8 inches in length and 1½ to 2 inches in circumference.

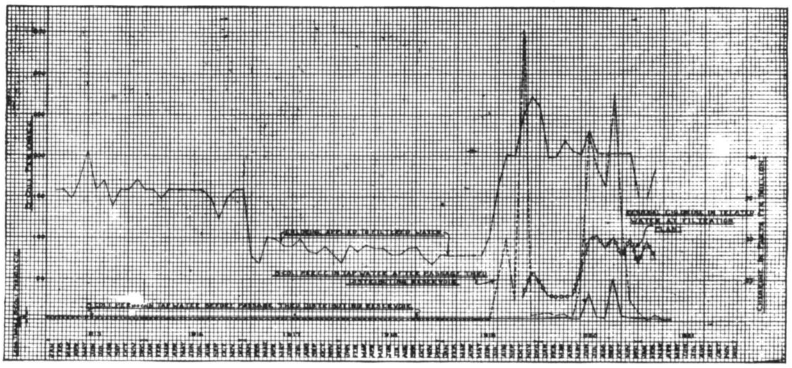

FIG. 2

During the summer of 1919 tadpoles were present in the reservoir in great numbers. It was thought inadvisable to attempt to kill these with copper sulphate, as it required comparatively heavy doses to accomplish this. In addition, it seemed unwise to kill so many of these organisms at one time.

Laboratory experiments were carried on with tadpoles taken from this reservoir and the results proved beyond question that these organisms are capable of giving off great numbers of B. coli. In passing it may be of interest to show to what extent these organisms may contaminate the supply.

Tadpoles were taken and thoroughly washed with sterile water and placed in 1 liter samples of water which had been previously sterilized. Shortly after placing the sterilized tadpoles in water samples were taken and analyzed and in every instance these samples did not show the presence of B. coli in 0.1, 1 or 10 cc. of water. After one hour's time samples were again taken from the water in which the tadpoles had been placed and B. coli was found in 0.001, 0.01, 0.1 and 1 cc. of the water tested.

A number of other tadpoles were sent to Dr. Salter, Bacteriologist of the State Department of Health of Maryland, who isolated B. coli of a fecal type from the intestines of the tadpoles.

From these findings there is no doubt in the mind of the writer that tadpoles in large numbers in the reservoir water were responsible for the high bacterial content of the water after passing through the Catonsville reservoir.

The question naturally arises as to why this condition did not appear prior to 1919. An explanation of this was difficult until a few weeks ago. After careful questioning of the operator in charge of the pumping station it was learned that prior to that year he had permitted a friend to come to the reservoir at night and hunt frogs. He informed me that not infrequently this man would obtain as many as a dozen large bullfrogs in one night. The removal of the frogs permitted little spawning in the reservoir water. During the spring of 1919 it became known that this practice was being carried on and the man in charge of the plant was ordered to prohibit anyone from entering the reservoir property without permission from the management of the Company.

It is reasonable to suppose, with an excessive B. coli content in the water, provided these organisms were due to failure of the purification system or from sewage contamination, that this condition would be reflected in the typhoid fever case rate in the territory supplied with the filtered and sterilized water. To determine this fact the typhoid fever case rates for Baltimore County have been plotted and are given in figure 3. The number of cases per 100,000 population is shown in the territory supplied exclusively with filtered water from the Avalon Plant. In addition, the typhoid fever case rates in Baltimore County, exclusive of the territory supplied from Avalon, are shown. It is seen from these curves that the typhoid fever rates in Baltimore County in these two territories follow each other very closely, indicating apparently no correlation between the character of the water and the typhoid fever.

In addition to these facts the curves show that in the period in which the greatest number of B. coli were reported in the filtered water the typhoid fever in the territory supplied with this water was extremely low.

Attention is directed also to the fact that prior to 1919, when the bacteriological quality of the water from the reservoir met the United States Treasury Department Standard, the prevalence of typhoid fever in this territory was much greater than when the quality of the water was poor.

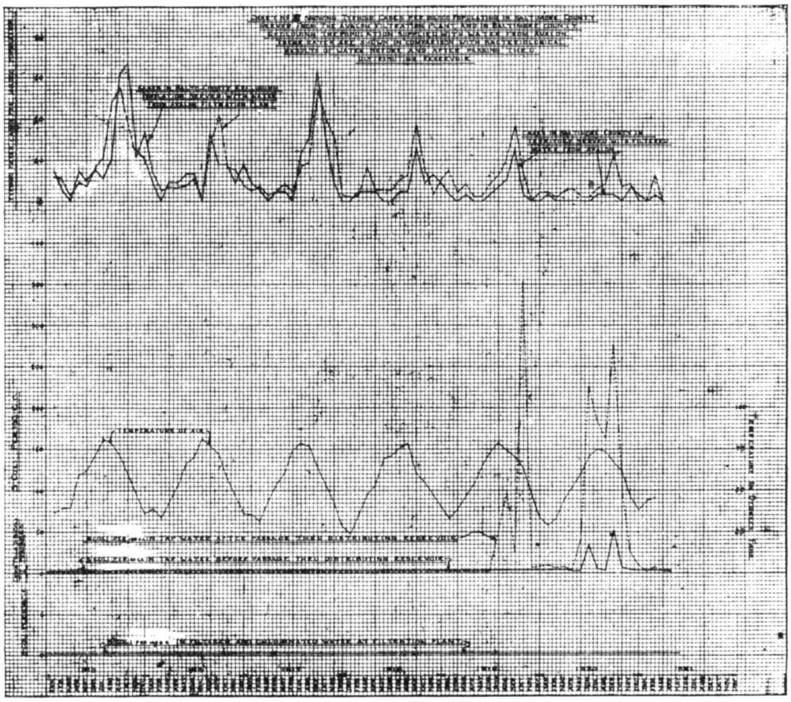

FIG. 3

In plotting these results the typhoid fever case rate has been used instead of the mortality rate. Owing to the proximity of this territory to the city, serious cases which might result fatally are often taken to the city hospitals and in case of death the mortality would be reported in the city and not in the county.

Several interesting problems present themselves as a result of this investigation. It is of primary interest to note the effect of an uncovered filtered water reservoir upon the bacteriological quality of the supply, which furnishes no small argument in favor of covering such reservoirs. Of no less interest is the interpretation of these bacterial data in judging the potability of the supply. The presence of the colon group isolated in large numbers from water indicates contamination of questionable character. In this investigation the water after passage through the Catonsville reservoir contained at times high colon content, but it was clearly evident that this was not contamination other than from tadpoles or possibly from birds. It demonstrates the inadequacy of our present bacteriological methods in indicating the true quality of a supply.